CLAIMS

1. A multi-stage optical amplifier, comprising:

an optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source that produces at least a signal wavelength λ_s and a pump source that produces a pump wavelength λ_p, wherein pump wavelength λ_p is less than signal wavelength λ_s;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction; and

a pump shunt coupled to the signal input port and the signal output port.

2. The multi-stage optical amplifier of claim 1, wherein the first and lengths of amplifier fiber each have a length greater than or equal to 200m.

3. The multi-stage optical amplifier of claim 1, wherein pump radiation of wavelength λ_p is in the range of 1300 nm to 1530 nm

4. The multi-stage optical amplifier of claim 1, wherein signal radiation of wavelength λ_s is in the range of 1430 to 1530 nm.

5. The multi-stage optical amplifier of claim 1, wherein the first lossy member is an optical isolator.

6. The multi-stage optical amplifier of claim 1, wherein the first lossy member is an add/drop multiplexer.

7. The multi-stage optical amplifier of claim 1, wherein the first lossy member is a gain equalization member.

8. The multi-stage optical amplifier of claim 1, wherein the first lossy member is a dispersion compensation element.

9. The multi-stage optical amplifier of claim 1, wherein the first length of amplifier fiber is a Raman amplifier.

10. The multi-stage optical amplifier of claim 1, wherein the second length of amplifier fiber is a Raman amplifier.

11. The multi-stage optical amplifier of claim 1, wherein at least one of the first and second Raman fiber amplifiers is a dispersion compensating fiber.

12. The multi-stage optical amplifier of claim 11, wherein the first and Raman fiber amplifiers are each dispersion compensating fibers.

13. The multi-stage optical amplifier of claim 1, wherein the first length of amplifier fiber has lower noise than the second length of amplifier fiber.

14. The multi-stage optical amplifier of claim 1, wherein the second length of amplifier fiber has a higher gain than the first length of amplifier fiber.

15. The multi-stage optical amplifier of claim 1, further comprising:

at least one WDM coupler to couple a pump path from the signal input port to the signal output port.

16. The multi-stage optical amplifier of claim 1, wherein the first length of amplifier fiber has an optical noise figure of less than 8 dB.

17. The multi-stage optical amplifier of claim 1, wherein the second length of amplifier fiber has a gain level of at least 5 dB.

18. The multi-stage optical amplifier of claim 1, further comprising:

a pump source coupled to the pump input port.

19. The multi-stage optical amplifier of claim 1, further comprising:

at least one laser diode pump source coupled to the pump input port.

20. The multi-stage optical amplifier of claim 1, further comprising:

a second lossy member coupled to the pump shunt.

21. The multi-stage optical amplifier of claim 1, wherein the pump shunt includes an optical fiber.

22. A broadband booster amplifier, comprising:

a plurality of transmitters transmitting a plurality of wavelengths;

a combiner coupled to the plurality of transmitters;

an optical fiber coupled to the combiner, the optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction; and

a pump shunt coupled to the signal input port and the signal output port.

23. A broadband pre-amplifier, comprising:

an optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction;

a pump shunt coupled to the signal input port and the signal output port;

a splitter coupled to the signal output port; and

a plurality of receivers coupled to the splitter.

24. A broadband communication system, comprising:

a transmitter;

an optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction;

a pump shunt coupled to the signal input port and the signal output port; and

a receiver coupled to the optical fiber.

25. The system of claim 24, wherein the first and lengths of amplifier fiber each have a length greater than or equal to 200m.

26. The system of claim 24, further comprising:

a pump source producing radiation of wavelength λ_p in the range of 1300 nm to 1530 nm

27. The system of claim 24, further comprising:

a signal source producing radiation of wavelength λ_s in the range of 1430 to 1530 nm.

28. The system of claim 24, wherein the first lossy member is an optical isolator.

29. The system of claim 24, wherein the first lossy member is an add/drop multiplexer.

30. The system of claim 24, wherein the first lossy member is a gain equalization member.

31. The system of claim 24, wherein the first lossy member is a dispersion compensation element.

32. The system of claim 24, wherein the first length of amplifier fiber is a Raman amplifier.

33. The system of claim 24, wherein the second length of amplifier fiber is a Raman amplifier.

34. The system of claim 24, wherein at least one of the first and second Raman fiber amplifiers is a dispersion compensating fiber.

35. The system of claim 34, wherein the first and Raman fiber amplifiers are each dispersion compensating fibers.

36. The system of claim 24, wherein the first length of amplifier fiber has lower noise than the second length of amplifier fiber.

37. The system of claim 24, wherein the second length of amplifier fiber has a higher gain than the first length of amplifier fiber.

38. The system of claim 24, further comprising:

at least one WDM coupler to couple a pump path from the signal input port to the signal output port.

39. The system of claim 24, wherein the first length of amplifier fiber has an optical noise figure of less than 8 dB.

40. The system of claim 24, wherein the second length of amplifier fiber has a gain level of at least 5 dB.

41. The system of claim 24, further comprising:

a laser diode pump source coupled to the pump input port.

42. The system of claim 24, further comprising:

a second lossy member coupled to the pump shunt.

43. The system of claim 24, wherein the pump shunt includes an optical fiber.

44. A broadband communication system, comprising:

a transmitter;

an optical fiber coupled to the transmitter, the optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction;

a pump shunt coupled to the signal input port and the signal output port;

at least one in-line broadband amplifier coupled to the optical fiber;

and

a receiver coupled to the in-line broadband amplifier.

45. The system of claim 44, wherein the in-line broadband amplifier comprises:

an optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction; and

a pump shunt coupled to the signal input port and the signal output port.

46. A broadband communication system, comprising:

a transmitter;

a broadband booster amplifier;

an optical fiber coupled to the broadband booster amplifier, the optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction;

a pump shunt coupled to the signal input port and the signal output port;

and

a receiver coupled to the optical fiber.

47. The system of claim 46, wherein the broadband booster amplifier comprises:

a plurality of transmitters transmitting a plurality of wavelengths;

a combiner coupled to the plurality of transmitters;

an optical fiber coupled to the combiner, the optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction; and

a pump shunt coupled to the signal input port and the signal output port.

48. A broadband communication system, comprising:

a transmitter;

an optical fiber coupled to the transmitter, the optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction;

a pump shunt coupled to the signal input port and the signal output port;

a broadband pre-amplifier coupled to the optical fiber; and

a receiver coupled to the broadband pre-amplifier.

49. The system of claim 48, wherein the broadband pre-amplifier comprises:

an optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction;

a pump shunt coupled to the signal input port and the signal output port;

a splitter coupled to the signal output port; and

a plurality of receivers coupled to the splitter.

50. A broadband communication system, comprising:

a transmitter;

a broadband booster amplifier coupled to the transmitter;

an optical fiber coupled to the booster broadband amplifier, the optical fiber including a first length of amplifier fiber and a second length

of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction;

a pump shunt coupled to the signal input port and the signal output port;

a broadband pre-amplifier coupled to the optical fiber; and

a receiver coupled to the broadband pre-amplifier.

51. The system of claim 50, wherein the broadband booster amplifier comprises:

a plurality of transmitters transmitting a plurality of wavelengths;

a combiner coupled to the plurality of transmitters;

an optical fiber coupled to the combiner, the optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction; and

a pump shunt coupled to the signal input port and the signal output port.

52. The system of claim 51, wherein the broadband pre-amplifier comprises:

an optical fiber including a first length of amplifier fiber and a second length of amplifier fiber, the optical fiber configured to be coupled to a signal source and a pump source;

a signal input port coupled to the optical fiber;

a signal output port coupled to the optical fiber;

a pump input port coupled to the optical fiber;

a first lossy member coupled to the optical fiber and positioned between the first and second lengths of amplifier fiber, the first lossy member being lossy in at least one direction;

a pump shunt coupled to the signal input port and the signal output port;

a splitter coupled to the signal output port; and

a plurality of receivers coupled to the splitter.